

### Remarks

This Preliminary Amendment cancels, without prejudice, claims 1-13 in the underlying PCT Application No. PCT/DE2004/001453 and adds new claims 14-26. The new claims, inter alia, conform the claims to United States Patent and Trademark Office rules and do not add any new matter to the application.

In accordance with 37 C.F.R. § 1.125(b), the Substitute Specification (including Abstract) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. §§ 1.121(b)(3)(ii) and 1.125(c), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) are respectfully requested.

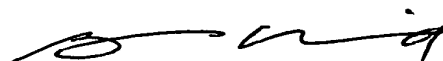
The underlying PCT Application No. PCT/DE2004/001453 includes an International Search Report, dated October 18, 2004, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON LLP

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By:   
Gerard A. Messina  
(Reg. No. 35,952)

One Broadway  
New York, NY 10004  
(212) 425-7200

## FUEL INJECTION SYSTEM

### Background Information

~~The present invention is based on a fuel injection system of the type set forth in the main claim.~~

From German Patent Application No. DE 100 26 321 A1, 321, for example, a fuel-

5 injection system having a fuel injector and an ignition device projecting into a combustion chamber is known. The fuel jets emerging from the fuel injector define a fuel cone. In the region of the spark plug, which is arranged in relatively close proximity to the fuel injector, the fuel cone has an angular section. Because of the angular section, two fuel jets are able to pass through the ignition device at a  
10 precisely defined distance, which is to ensure reliable ignition of the fuel.

A particular disadvantage of the fuel-injection system known from the aforementioned publication is that the fuel injector must be installed very carefully in order to precisely align the angular section with respect to the spark plug. In addition,  
15 the ignition device or the arrangement of the poles or electrodes must be mounted in such a way that it assumes an exactly defined position with respect to the fuel injector. The position of the ignition spark of an ignition device and the position and geometry of the jet pattern of the fuel injector must change only negligibly over the entire service life of the fuel-injection system so as to avoid misfirings, for example.

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### Summary of the Of The Invention

~~In contrast, the~~ The fuel injector according to the present invention ~~having the characterizing features of the main claim~~ has the advantage over the related art that, in particular, the installation of the fuel-injection system is simplified considerably.

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In particular, the ignition device or the arrangement of the poles or electrodes need not be aligned in relation to the fuel injector in a complicated manner. Neither does the fuel injector require labor-intensive alignment by rotation about the longitudinal axis.

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The penetration depth of the ignition device into the combustion chamber is reduced, so that, for instance, the thermal loading of the ignition device, especially the poles,

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is reduced. The size of the ignition device is scalable, and the jet cone is ignited at the outer envelope.

~~Advantageous further developments of the fuel injection system specified in the main claim are rendered possible by the measures given in the dependent claims.~~

In an advantageous manner, the end of the first pole and the end of the second pole are at least partially made of a noble metal, especially a platinum alloy. In this way the ignition spark is generated in a reliable manner only between the two ends, without being carried out of the region of the poles or the electrodes. The fuel may thus be ignited in a more reliable manner since little energy is given off to the electrodes in the form of heat as happens in undesired so-called creepage sparks, for instance.

It is also advantageous if the diameter of the ends of the first pole and the second pole amounts to less than one millimeter and/or if the distance between the end of the first pole and the end of the second pole is less than one millimeter. This, too, ensures that the spark is always generated in the same spot between the poles and remains there during the ignition process.

In a further development of the fuel injector according to the present invention the distance between the second pole and the cone envelope is between 0.5 and 3 mm. This provides reliable ignition, and the thermal loading of the ignition device is considerably reduced by the arrangement of the ignition device resulting therefrom, which leads to longer service life and exchange intervals.

The spray-discharge orifices, which widen towards the combustion chamber in a stepped manner, reduce or prevent the formation of deposits that may affect the geometry of the spray-discharged fuel in an undesired manner.

When using a multi-hole disk in which the spray-discharge orifices are arranged, the fuel injector and thus the fuel-injection system may be configured in a much simpler manner.

#### Brief Description of the Drawing

~~An exemplary embodiment of the present invention is depicted in simplified fashion in the drawing and explained in greater detail in the description below.~~

~~The figures show:~~

~~Fig. 1~~ Figure 1 shows a schematic section through an exemplary embodiment of a fuel injector configured according to the present invention;

5 ~~Fig. 2~~ Figure 2 shows a schematic section through the exemplary embodiment of the fuel-injection system according to the present invention, along line II-II in Figure 4;

~~Fig. 3~~ Figure 3 shows a schematic section through the discharge-side end of a fuel injector of a fuel-injection system according to the present invention;

10 ~~Fig. 4~~ Figure 4 shows a schematic representation of the end, projecting into the combustion chamber, of an ignition device of a fuel-injection system according to the present invention;

15 ~~Fig. 5~~ Figure 5 shows a schematically illustrated jet pattern of a fuel injector of a fuel-injection system according to the present invention, the fuel injector producing a conical envelope;

20 ~~Fig. 6~~ Figure 6 shows a schematic section through another exemplary embodiment of a fuel-injection system designed according to the present invention; and

~~Fig. 7~~ Figure 7 shows a schematically illustrated jet pattern of a fuel injector of a fuel-injection system according to the present invention, the fuel injector producing an envelope in the form of a partial cone.

25 Detailed Description

An exemplary embodiment of the present invention is described below by way of example. Identical parts are provided with matching reference numerals in all of the figures.

30 An exemplary embodiment of a fuel-injection system 1 according to the present invention and illustrated in Figure 1 is configured for mixture-compressing combustion engines having externally supplied ignition and internal mixture formation and combustion as well as jet-directed combustion method.

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In this exemplary embodiment, fuel-injection system 1 includes a cylinder 21 in which a piston 3 is guided. On one side, piston 3 is connected to a connecting rod 4 and, on the other side, it adjoins a combustion chamber 6. Combustion chamber 6 is also delimited by cylinder 21 and a cylinder head 5, which is disposed on the side of cylinder 21 facing away from connecting rod 4. Cylinder head 5 has a conical recess 12 that widens in the direction of cylinder 21 and forms a portion of combustion chamber 6. Coaxially arranged in recess 12 is a fuel injector 2 whose discharge-side end projects into combustion chamber 6. Fuel jets 20, which emerge from the discharge-side end of fuel injector 2 and are schematically illustrated in Figure 5, spread a cone-shaped fuel fan 11 having an envelope-opening angle  $\alpha$ , which preferably amounts to 70 to 110 degrees. Relatively close-by, at a slight lateral offset with respect to the discharge-side end of fuel injector 2, an ignition device 8 projects into combustion chamber 6 or into recess 12 to such a degree that a clearance of preferably 0.5 mm to 3 mm remains with respect to a fuel fan 11 forming a cone envelope 18. The fuel/air mixture produced in combustion chamber 6 is ignited by ignition device 8.

Furthermore, at least one discharge valve 10 and at least one intake valve 9 are likewise arranged in cylinder head 5.

Figure 2 shows a schematic section through the exemplary embodiment of fuel-injection system 1 according to the present invention, along line II-II in Figure 1. Clearly visible is the centered position of fuel injector 2 in recess 12 as well as the position of ignition device 8 arranged a short distance therefrom at a lateral offset. In this representation, first pole 16 is located on the side of second pole 17 facing away from fuel injector 2. Due to the inventive measures, the position of first pole 16 is irrelevant, however, which simplifies the installation of ignition device 8. For instance, if ignition device 8 is screwed into cylinder head 5, the position of ignition device 8 or first pole 16 will not need to be controlled very carefully during installation and the threads on cylinder head 5 and ignition device 8 need not be produced with high manufacturing tolerances. Furthermore, no defined installation location of pole 16 on ignition device 8 will be required.

Figure 3 shows a schematic section through the discharge-side end of a fuel injector 2 of a fuel-injection system 1 according to the present invention, which has a valve-seat body 15, a valve needle 14 and spray-discharge orifices 13 of which only one is shown. Spray-discharge orifices 13 widen in a stepped manner in the direction of combustion chamber 6. This prevents or lessens the formation of deposits in the region of spray-discharge orifice 13.

Figure 4 shows a schematic illustration of the end of an ignition device 8 of a fuel-injection system 2 according to the present invention, this end projecting into combustion chamber 6. The end of the at least one first pole 16 is disposed to the side of the end, projecting into combustion chamber 6, of second pole 17, both ends being situated at approximately the same level of the longitudinal axis of ignition device 8. Both ends are preferably made of a platinum alloy so as to keep the ignition spark between the ends of poles 16, 17 during the entire ignition process. The diameters of the ends and their mutual clearance preferably amount to less than 1 mm.

Figure 5 shows a schematically illustrated jet pattern formed by a fuel injector 2 of a fuel-injection system 1 according to the present invention, this fuel injector generating a cone envelope. Fuel jets 20, evenly spread to form a cone envelope 18, have an opening angle  $\beta$  of approximately 25 degrees relative to the respective adjacent fuel jet 20. In other exemplary embodiments, opening angle  $\beta$  may amount to between 25 and 45 degrees, and it is possible that the individual opening angles  $\beta$  of the preferably 4 to 12 fuel jets 20 produced by one spray-discharge orifice 13 in each case deviate from each other.

In the exemplary embodiment shown, the position of ignition device 8 relative to the discharge-side end of fuel injector 2 is approximately between two fuel jets 20, the position of fuel jets 20 relative to ignition device 8 being freely selectable as a result of the measures according to the present invention. Fuel jet 20 may, for instance, extend also exactly above ignition device 8. Analogously to the installation of ignition device 8, the installation of fuel injector 2 is considerably simplified thereby as well. If fuel injector 2 is screwed into cylinder head 5, for instance, the position of fuel injector 2 will not require precise control during installation and the threads on

cylinder head 5 and fuel injector 2 need not be produced with high manufacturing tolerances. The number of fuel jets 20 generated by one spray-discharge orifice 13 is preferably between 4 and 12 in each case.

- 5 Figure 6 shows a schematic section through another exemplary embodiment of a fuel-injection system 1 configured according to the present invention, which is similar to the exemplary embodiment of Figure 1. However, ignition device 8 is arranged coaxially or at the highest point of recess 12. In this exemplary embodiment, ignition device 8 is thus arranged coaxially with respect to combustion chamber 6 as well.
- 10 Relatively close by, at a slight lateral offset with respect to ignition device 8, the discharge-side end of fuel injector 2 projects into recess 12 to such an extent that a clearance of preferably 0.5 to 3 mm remains relative to cone envelope 18.

- Figure 7 shows a schematically illustrated jet pattern of a fuel injector of a fuel-injection system according to the present invention, the fuel injector producing a part-conical envelope. Fuel fan 11 or cone envelope 18 which emerges from fuel injector 2 in a non-coaxial manner and is only partially formed in this exemplary embodiment, namely in the form of a partial cone envelope, has 7 fuel jets 20 having uniform opening angles  $\beta$  of 40 degrees with respect to each other. In other exemplary
- 20 embodiments, different opening angles  $\beta$  between fuel jets 20 may be chosen as well, depending on the processes taking place in combustion chamber 6. The position of the discharge-side end of fuel injector 2, which projects into combustion chamber 6, is located outside the center point of the cross-sectional plane of combustion chamber 6, as is the position of the discharge-side end of ignition device
- 25 8.

The present invention is not restricted to the exemplary embodiment shown, but may be used for any other internal combustion engine having fuel injection.

### Abstract of The Disclosure

#### Summary

A fuel-injection system (1) comprising a fuel injector (2), having a plurality of spray-discharge orifices (13) including a fuel injector, having a plurality of spray-discharge orifices, which meters fuel into a combustion chamber (6) of an internal combustion engine, has an ignition device (8), which projects into the combustion chamber (6), this ignition device (8) having at least one first pole (16) and one second pole (17). The fuel jets (20) emerging from the spray-discharge orifices (13) spread an essentially cone-shaped fuel fan (11) below the region of the ignition device (8). The end of the at least one first pole (16) is arranged to the side adjacent to the end of the second pole (17) projecting into the combustion chamber (6), and both ends are located on approximately the same level of the longitudinal axis of the ignition device (8).

(Figure 4)